Stormwater Runoff Management

Are Real Water Quality Problems Being Addressed by Current Structural Best Management Practices?

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THE BASIC question is related to practicality and cost-effectiveness—that is, are the structural stormwater control devices being installed in many areas of the country actually doing the job for which they are designed? Public works directors for many cities and counties, and stormwater management agencies are involved in developing programs designed to implement "best management practices" (BMPs). These structures supposedly control chemical contaminants in stormwater runoff from urban areas. Numerous articles have been published in PUBLIC WORKS and other publications devoted to how a particular city, stormwater quality management entity, consulting firm, and/or regulatory agency is developing structural BMPs, such as detention basins, grassy swales, infiltration systems, and so forth, for stormwater quality management. What is not frequently discussed is that such BMPs are constructed at considerable public or private expense.

Current activities in stormwater quality management have evolved from the EPA's National Urban Runoff Program (NURP) begun in the 1970s. An extension of that program was established in 1990 to implement the stormwater-related provisions of the 1987 amendments to the Clean Water Act. Those provisions required a new NPDES (national pollution discharge elimination system) permit system for urban stormwater discharges from cities with populations greater than 100,000, as well as from selected industries and new developments. The EPA's current program requires that stormwater "pollution" be controlled to the "maximum extent practicable." However, what is meant by the word, "pollution," or by the concept of pollution control to the "maximum extent practicable" has not been defined by Congress, the EPA, state pollution control agencies, or local stormwater control agencies. This article discusses issues of assessing real pollution, i.e., *designated beneficial use impairment* in receiving waters, that stormwater runoff causes. Without a clear understanding of the pollution caused (or not caused) by runoff, it is obviously not possible to develop technically valid, cost-effective control programs that control pollution to the "maximum extent practicable."

Current Approaches

Large amounts of public and private funds are now being allocated for constructing structures ostensibly to protect water quality and, for existing discharges, to enhance water quality. However, it is the authors' experience that with few exceptions, a number of significant, inappropriate assumptions are made when assessing potential impacts to water quality and beneficial uses, and selecting and developing BMPs for runoff quality management. It is commonly taken for granted that contaminants in existing urban stormwater runoff are having significant adverse impacts on the quality of the waters receiving those discharges. It is also taken for granted that a particular structural BMP will be effective in controlling the chemical contaminants in runoff that are allegedly detrimental to receiving water quality. However, as discussed herein, there are few documented cases in which urban stormwater-associated chemical contaminants, not derived from illegal connections or illicit dumping, are having a significant adverse impact on the designated beneficial uses of the receiving waters. Furthermore, many of the off-the-shelf structural BMPs that are used today have limited efficacy in controlling those portions of chemical contaminants in urban stormwater runoff that have a potential to adversely impact water quality.

Table 1 - Water Quality Characteristics of Runoff from Residential and Commercial Areas[a]

Constituent	Average Concentration[b]
TSS	239.0
BOD	12.0
COD	94.0
Total P	0.5
Soluble P	0.15
TKN	2.3 mg/L
NO_2+NO_3[c]	1.4 mg/L
Total Cu	53.0 μg/L
Total Pb	238.0 μg/L
Total Zn	353.0 μg/L

[a] From the ASCE and WEF manual of practice[4] and the EPA NURP report.[5]
[b] Residental or commercial sites.
[c] As N.

Public works directors and others responsible for developing and implementing urban stormwater management programs have little reason to doubt that chemical contaminants in urban stormwater discharges are causing highly significant water quality problems. They frequently receive information from federal and state agencies claiming that urban stormwater associated chemical contaminants are responsible for major water quality problems. Based on its National Water Quality Inventory report to Congress, the EPA stated:

> Based in part on national assessments conducted by the U.S. Environmental Protection Agency (EPA) it is now recognized that nonpoint sources and certain diffuse point sources (e.g., stormwater discharges) are responsible for between one-third and two-thirds of existing and threatened impairments of the nation's waters (U.S. EPA, 1991).[1]

The "National Water Quality Inventory 1992 Report to Congress," indicated that urban stormwater runoff ranks second in importance as the source of water quality impairment for U.S. lakes and estuaries, and third as the source of water quality impairment of U.S. rivers.[2] However, examining the basis upon which that conclusion was drawn shows it to be inappropriate for assessing stormwater impact on water quality.

Protecting Water Bodies

U.S. water quality management practices are based on protecting and/or enhancing the designated beneficial uses of water bodies. Stormwater discharges are generally a subject of concern because of high concentrations of various chemical contaminants. These contaminants have the potential to be toxic or to produce other adverse effects to aquatic life in the receiving waters. The typical discussion of stormwater quality "impacts," such as that which evolved from the results of the EPA's NURP as reported by Pitt and Field[3] and more recently by the American Society of Civil Engineers (ASCE) and Water Environment Federation (WEF)[4] in their manual entitled, *Design and Construction of Urban Stormwater Management Systems.* This manual focuses on presenting test results of chemical contaminant concentrations found in stormwater runoff. This can be illustrated by Table 1, a partial representation of a table found in the manual (which in turn was developed from the EPA's NURP results).[5] The table's title, however, seems inappropriate and would have been more properly titled, "Average Concentrations of Selected Chemical Characteristics of Runoff from Residential and Commercial Areas." As discussed below, there is no way to reliably judge the water quality characteristics of urban stormwater runoff based on a "laundry list" of chemical concentrations found in the runoff presented in this table. Trying to judge water quality impacts from such information is analogous to trying to judge the characteristics of clothes based on a the "average" list received by a laundry. While the laundry list presents an inventory of the number of shirts, pants, ties, etc. in the laundry, it provides no information on the fit, stylishness, color-coordination, suitability for an occasion, etc. of the clothing for a person.

Chemicals In Different Forms

The NURP data in the table provides information on the average concentrations of a few chemicals found in urban stormwater runoff. However, it provides no reliable information on the potential significance of those characteristics to water quality in general or for a particular urban stormwater runoff situation. Chemical contaminants exist in a wide variety of chemical forms. Only some of those forms are available to adversely affect water quality and the water body's beneficial uses. For example, copper occurs in urban stormwater and highway runoff at elevated concentrations relative to federal and state water quality criteria and standards for fresh and marine waters. These forms include several soluble types of copper, such as the uncomplexed copper ion, a variety of inorganic complexes with hydroxyl and carbonate species, various organic complexes with natural and anthropogenic organics, and many different particulate forms (such as copper metal, copper precipitates, and copper sorbed on particles—suspended solids and colloids). Several studies have shown that only a very small part of the total copper present is in a toxic-available form. Only the copper aquo ion (unreacted copper ion, $Cu(H_2O)_4^{2+}$), some of the hydroxyl complexes, and some of the weak organic complexes are toxic. All of the strong complexes, both soluble and particulate, and all forms of particulate copper are non-toxic. The chemical analytical methods available, however, do not distinguish among the toxic and non-toxic forms of the soluble copper species.

Determining contaminant availability cannot be made based on the chemical's total concentration, especially in a matrix such as urban stormwater runoff. For a chemical contaminant to adversely affect the aquatic life's beneficial use, it must adversely impact the numbers, types, and/or characteristics (such as the wholesomeness of fish or other aquatic creatures in the receiving water) to a sufficient extent that causes concern and then requires spending funds to control the problem. To evaluate the water quality impact, it is necessary to develop a site-specific understanding of the aquatic chemistry and aquatic toxicology of the chemical contaminants present in the stormwater runoff and in the particular waters receiving the runoff. This includes acquiring site-specific information on the physical, chemical, aquatic life, and beneficial use characteristics of the receiving waters.

Reliable Chemical Assessments

Obviously, there is need to develop appropriate management approaches to alleviate real water quality problems (i.e., impairing the beneficial use of the water body) caused by chemical contaminants in urban runoff. This means effectively controlling those particular contaminant forms that adversely impact the designated beneficial uses. This involves a reliable chemical impact assessment as well as developing suitable control measures that do not involve unnecessary expenditures for controlling unavailable chemical forms.

A critical review of the physical and chemical characteristics of urban stormwater runoff and the aqueous environmental chemistry of the contaminants shows that it would be rare that conventional structural BMPs (e.g., detention basins, grassy swales, and infiltration systems) would adequately address water quality problems caused by runoff-associated contaminants. That notwithstanding, there is a strong advocacy for contaminant control programs that require large expenditures of public funds for installing structural BMPs. This concept is based solely on the fact that runoff contains elevated concentrations of chemicals and/or that the contaminants in the runoff persist in the receiving waters by accumulating in sediments.

A chemical contaminant's impact on a beneficial use related to aquatic life depends on the concentrations of the chemical's available forms in the receiving water, and the duration of an organism's exposure to particular concentra-

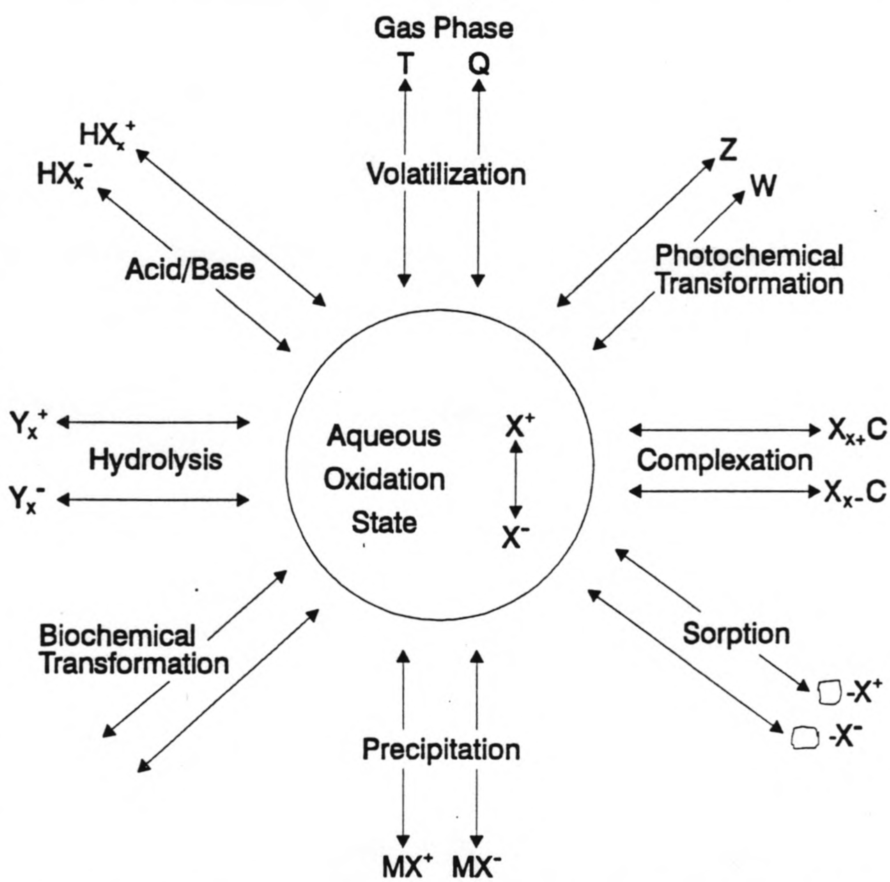

FIGURE 1. Distribution depends on kinetics and thermodynamics of reactions in a particular aquatic system. Each chemical has its own toxicity characteristics. Many forms are non-toxic. Toxic forms are typically aqueous aquo-species of metals.

tions of those available contaminant forms. The former is controlled by the nature of the chemical contaminants and the types and rates of their chemical reaction/transformation in the receiving water. The influence of the latter depends on the types and sensitivity of the aquatic organisms in the particular water body. These factors are all described by the aqueous environmental chemistry (aquatic chemistry) and aquatic toxicology of the particular situation. Thus, it is necessary to reliably evaluate both the aquatic chemistry and the associated aquatic toxicology of chemical contaminants.

What is and What is Not a Problem

Aquatic Chemistry. It has been known for more than 20 years that while the total concentration of certain chemicals in urban stormwater runoff may be high, the elevated concentrations of contaminants do not necessarily adversely impact real water quality. Figure 1 illustrates fundamental reactions of aqueous environmental chemistry, i.e., key reactions that chemical contaminants can undergo in aquatic systems. Each of the chemical reactions can result in the conversion of toxic/available forms of contaminants into non-toxic, unavailable forms. These latter forms though, are included in the determination of the total contaminant concentration.

Reactions of particular importance relate to the tendency of many contaminants to associate with particulates. Such contaminants tend to be unavailable and in effect, non-toxic to aquatic life. Thus, while urban stormwater runoff can have high total concentrations of a wide variety of contaminants such as copper and other heavy metals, such contaminants are typically present as non-toxic, unavailable particulate forms. In such forms, they do not adversely impact the designated beneficial uses of the waters receiving the stormwater runoff. This point is especially noteworthy with regard to stormwater management programs because many of the BMPs focus on removing particulates and their associated contaminants.

Aquatic Toxicology. Aquatic toxicology goes hand-in-hand with aquatic chemistry in assessing impacts on aquatic life. It describes the response that an organism may have when exposed to contamination, including the availability of particular chemicals. It also describes the conditions of organism exposure that elicit adverse responses that, in this context, significantly influence the receiving water's designated beneficial uses. Some of these conditions include the duration of exposure, the frequency of exposure, the organism's stage of development or age, and the organism's sensitivity. Each condition affects or modifies the impact that a given chemical contaminant has on organisms and hence on aquatic life-related beneficial uses.

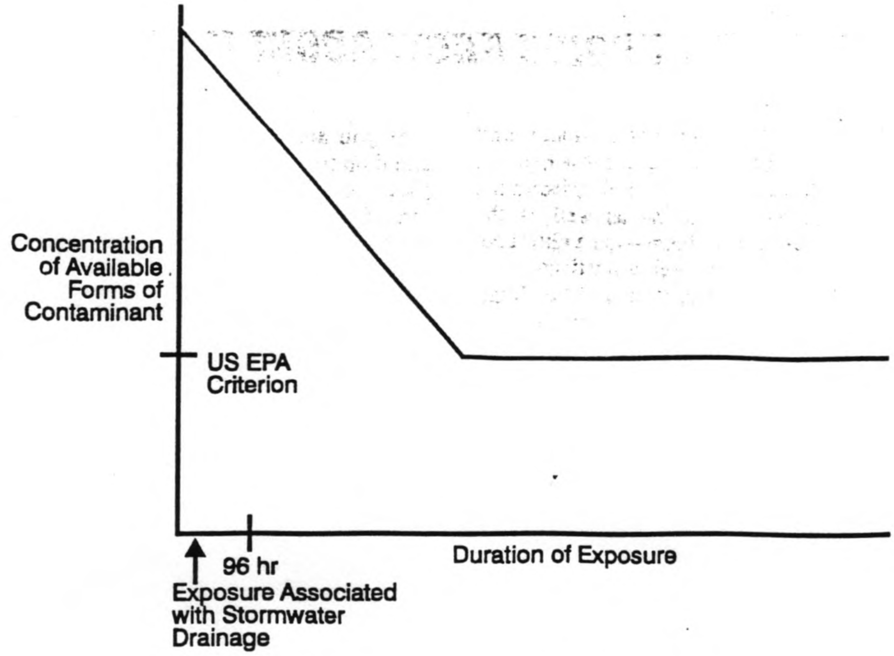

FIGURE 2. US EPA criteria list 1-hr-average maxima and 4-day average maxima. Not valid for assessing potential impacts of urban stormwater drainage.

Duration and Exposure

One of the key elements of aquatic toxicology is the duration of organism exposure. Figure 2 illustrates a generic relationship among the conditions of concentration of available forms and duration of exposure (stippled area), which indicates the area of potential impact from toxic contaminants.

The concentration of the contaminant's available forms to which organisms can be exposed for a lifetime without adverse impact (the horizontal delimiting line in Figure 2) is often selected as the water quality criterion or standard value. As shown, the presence of available contaminant forms in concentrations well-above federal and state water quality criteria and standards do not adversely impact beneficial uses as long as the duration of exposure is sufficiently short. The shorter the exposure duration, generally the higher the concentration of contaminants to which the organism can be exposed without adverse impact. Very high concentrations of toxic-available forms of contaminants can be present for short periods without adversely affecting aquatic life. This is of particular importance when considering potential runoff impacts since stormwater events tend to be episodic in nature. Receiving water organisms then, receive short-duration exposures to the associated chemical contaminants. Furthermore, in many situations, stormwater runoff undergoes rapid dilution in the receiving waters. This diminishes the concentrations of contaminants to which organisms are exposed.

The Troubling Regulatory Approach

The EPA's National Water Quality Inventory (NWQI) ranked urban stormwater runoff as the second/third-highest cause of water quality problems in the U.S. That ranking, however, was a result of the methodology employed in the NWQI and does not properly reflect the water quality significance of that source. In conducting the NWQI, the EPA required state agencies to consider violations of a chemical's specific water quality standard as tantamount to water quality impairment. As shown in Table 1, urban stormwater runoff commonly contains a variety of chemical contaminants which, in *total* concentrations, often exceed federal and state water quality standards. This, in turn causes the receiving waters at the point of stormwater discharge during the storm event to have chemical contaminant concentrations above state numeric water quality standards. As the EPA arbitrarily adopted a requirement that the state numeric chemical water quality standards cannot be exceeded for more than one hour once in three years, there are consequently many "violations" of state water quality standards.

To consider a violation of a water quality standard as equivalent to water quality "impairment" disregards the aquatic chemistry and aquatic toxicology of the stormwater-associated chemical contaminants. Exceeding a water quality standard is an "administrative exceed-

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ence"—it does not necessarily represent an impairment of the aquatic life-related designated beneficial uses of the water. That is, it does not cause a significant diminution of the numbers, types, and characteristics of aquatic life in the receiving waters. Judging the need for "management" based on administrative exceedances of the currently used numeric standards is a questionable practice. Such a requirement can be expected to result in excessive and perhaps unwise expenditures for programs that effect little or no

improvement in the designated beneficial uses of a water body.

Cost-Effectiveness Not A Prime Concern

In the past, the cost-effectiveness of contaminant control was rarely considered in developing water pollution control programs. The Clean Water Act made only limited provision for considering cost-effectiveness of control programs. This has resulted in water quality criteria being based on worst-case or near worst-case assumptions about the impacts of chemical contaminants on aquatic life. Control approaches were then developed from grossly overestimated impacts. Until recently, the chemical contaminant's aquatic chemistry was largely ignored when establishing and implementing the criteria—all forms of a contaminant were assumed to be toxic and in available forms. Further, as noted above, the criteria were developed and implemented assuming long-term or critical life stage (chronic) exposure conditions; they do not consider the short-term, episodic nature of stormwater discharges.

It has been suggested that it is the responsibility of the states when developing standards and enforceable limits, to consider issues of cost-effectiveness in evaluating the need and approaches for contaminant control. However, many states have taken a bureaucratically expedient, but technically vacant approach, of simply adopting EPA water quality criteria as the state's water quality standards. This approach fails to provide appropriate consideration to the grossly over-protective nature of those criteria/standards to many point- and non-point-source discharge/runoff situations.

Therefore, because of the way data was required to be reported for the NWQI, it is not surprising that the states' information would indicate that urban stormwater runoff-associated chemical contaminants are a major cause of water quality impairment. However, it is the authors' experience that it will be rare that the chemical contaminants present in typical urban and commercial runoff will, in fact, impair the designated beneficial uses of the receiving waters.

Over-Emphasis on Sediments Skews Concerns

Another aspect of the NWQI that is of concern is its focus on contaminants accumulating in the receiving water body's sediments. To that end, the EPA is asking states to report sediments with elevated concentrations of chemical contaminants as part of the inventory assessment. It has been well-understood since the 1960s that there is no relationship between the total concentration of chemical contaminants in sediments and the impact of those chemical contaminants on water quality. Unfortunately, there is still a

tendency by agencies to use sediment concentrations of selected contaminants as a basis for judging the impacts of those sediments on water quality. Because of the inherent technical deficiencies in that approach its use can lead to inappropriate water quality assessments. Specifically, the over-emphasis on particulate and strong soluble complex forms of chemical contaminants. This approach is of concern since many of the chemical contaminants in urban stormwater runoff are in particulate forms or are associated with particulate matter. Further, substantial parts of the "dissolved" metals in urban stormwater runoff are in colloidal forms or exist as metal complexes.

Because of contaminants accumulating in sediments, structural BMPs such as detention basins have been espoused as a means to trap runoff particulates. These arguments are without technical foundation. Such assessments cannot be made based on the total composition of stormwater runoff or receiving water sediments. Techniques such as benthic organism bioassays and fish tissue analysis to detect chemical bioaccumulation have been available for about 20 years. These techniques more reliably assess whether chemical contaminants in sediments are potentially adverse to aquatic life and related beneficial uses of water bodies.

The first part of this article has discussed some of the problems associated with current practices of regulating stormwater contaminants. These practices then lead to overly-cautious controls and expensive structural "solutions." It is hoped that the information presented here will lead to further discussion and a more realistic assessment of how BMPs can be achieved cost-effectively. □□□

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Part One of this article discussed some of the problems associated with current practices of regulating stormwater contaminants. These practices have led to overly-cautious controls and expensive structural "solutions." Part Two continues the discussion about problems with the existing regulatory framework and examines some different approaches. It is hoped that the information presented here will lead to an expanded dialog with a flexible and a more realistic look at how best management practices can be achieved cost-effectively.

MUCH CONCERN has been expressed about the need to control stormwater discharges to prevent contaminating the receiving water body. However, it is apparent that many well-intentioned control programs were implemented before the extent and nature of this pollutant source were fully studied. Because of the way chemicals can exist in different forms and the way some are bound into sediments, the actual impact of these contaminants can be much less than they are perceived to be. Many structural BMP (best management practice) controls seek to mitigate the worst possible scenario, which may be a scenario that does not actually occur. The resulting control measures then represent a waste of time, money, and effort, and do little to correct the perceived problem. Much more work has to be done to determine when material discharged through a storm sewer actually does represent a significant harm to a receiving water body's quality.

One documented case of inappropriately classifying a waterbody as "impaired" (partially because of urban stormwater discharges) is San Francisco Bay. Total copper concentrations in the waters of San Francisco Bay, like many other estuarine bays near large urban centers, exceed the EPA water quality criterion of 2.9 μg/L. Since, according to EPA, a state's numeric water quality standard cannot be exceeded for more than one hour once in three years, the Bay is often in violation. (Total copper concentrations in Bay waters typically range from 10 to sometimes as high as 15 μg/L).

Because of that finding the San Francisco Bay Regional Water Quality Control Board (SFBCB) had to list the bay as an "impaired-use" waterbody. That listing in turn, requires that waste load allocation and total maximum daily load (TMDL) for copper be developed for all external sources of copper to the Bay. This includes stormwater runoff because of the potential toxicity of copper to aquatic life in the watercolumn. Stormwater management agencies are now trying to develop programs to control copper to meet their TMDLs. However, toxicity studies on San Francisco Bay waters have repeatedly shown that those waters are not toxic to aquatic life. This means that exceeding the water quality criterion/standard for copper in the Bay is an "administrative exceedance" and is not causing impairment of the designated beneficial uses of the Bay waters.

Different Approach Required

Unless the regulatory agencies adopt a different approach, more than a billion dollars will be spent controlling copper in San Francisco's stormwater runoff. This control work is being done despite the fact that even if all copper discharges to the Bay are eliminated, the stirring of Bay sediments into the watercolumn during storms will still result in exceeding the water quality copper criterion. This is in addition to the fact that testing has shown no toxicity problems in the Bay waters from copper or by other contaminants.

In the mid-1980s, the EPA did develop an approach for modifying its water quality criteria to give consideration to site-specific water chemistry. However, the "water effects ratio" (WER) adjustment approach does not consider the most important aspect of copper chemistry to point- and non-point-source dischargers, that is, the relationship between the contaminants' chemical forms and the forms of the contaminant used in the WER testing. Following EPA guidance, the SFBCB conducted a WER evaluation and was able to raise the copper water quality objective for San Francisco Bay waters from 2.9 to 4.9 μg/L. However, that adjustment is inadequate since Bay waters already contain copper in concentrations at least twice the revised figure. Yet the waters show no toxicity when evaluated using the same types and stages of organisms that were originally used to establish the standard.

Unfortunately the EPA's recently released *Interim Guidance on Determination and Use of Water-Effect Ratios for Metals*[1] manual does not address the toxicity of specific chemical forms. This is the most significant and fundamental problem in using the WER approach for assessing the impacts of stormwater runoff. A regulatory approach needs to be developed that more appropriately considers how chemical contaminants in urban stormwater runoff (and for that matter, in many other sources) impact the designated beneficial uses of a waterbody. Without such an approach, massive amounts of public and private funds will be wasted constructing BMPs for urban stormwater runoff-associated contaminants that will produce little or no improvement in the designated beneficial uses of waters receiving those discharges.

Suggested Approaches

As part of working with Congress during reauthorization of the Clean Water Act, the California Stormwater Quality Task Force proposed language that would require EPA to develop wet-weather water quality criteria that could be used by states to regulate chemical contaminants in urban and rural stormwater runoff. Those criteria/standards would be developed to more appropriately consider the aquatic chemistry and aquatic toxicology of runoff-associated chemical contaminants as opposed to using the current EPA criteria and state water quality standards. Whatever the mechanism, it is clear that a more appropriate regulatory approach is necessary to avoid wasting limited funds.

Typically, the structural BMP for a particular situation is selected from a list of such techniques that have been used or have been proposed for use for many years (such as detention basins, grassy swales, and infiltration systems). Such BMPs have been developed and used over the years largely for addressing hydraulic concerns, with limited regard for their efficacy in controlling chemical contaminants in stormwater runoff. A critical review of the nature of the structural BMPs indicates that many of them produce little or no improvement in the designated beneficial uses of the receiving waters.

For a structural BMP to be cost-effective it must in fact control those forms of the chemical contaminant of concern that are adversely impacting designated beneficial uses. Further, the degree of improvement in beneficial uses that would accrue from the placement of such a BMP should be able to be determined.

The Detention Basin Fallacy

One of the most common BMPs for urban stormwater runoff is the detention basin. In such a basin, stormwater runoff, especially from low to moderate flows, is detained for a period of time to allow particulates, and their associated contaminants, to settle. However, as previously noted, the particulate forms of chemical contaminants removed in detention basins are typically non-toxic. Their accumulation in receiving water sediments rarely causes water quality problems. Where there is a potential problem with toxic chemicals in urban stormwater drainage, it is likely to be caused by dissolved fractions—substances that are typically not removed by a detention basin.

Controlling lead in urban and highway runoff with detention basins (sometimes called sediment traps) is an example of an inappropriate control method. The lead present in this type runoff is typically in particulate forms and is non-toxic to aquatic life both in the watercolumn and in the sediments. While some of the particulate lead in stormwater runoff can be trapped in detention basins and similar devices, much of the finely divided particulate lead and the dissolved lead pass through such systems with little or no removal. Thus this would be an expensive structure of dubious benefit and would do little, if anything, to improve water quality.

For a situation in which there is concern about lead in a particular stormwater discharge stream, the authors recommend that before any efforts be made to develop a BMP that real water quality problems associated with lead be determined. If the problem cannot be rectified by controlling the source of lead responsible for the problem, then the BMP for this situation should emphasize removing only those forms of lead that cause the water quality problem. It is noted that the techniques required for removing the fraction of dissolved lead causing the water quality problem could still be very expensive. However, while present day structural BMPs will largely be cosmetic and ineffective in controlling real water quality problems caused by lead, the appropriate treatment BMP would address real water quality problems caused by lead and control them.

Moving the Problem Is Not a Solution

The sediment that accumulates in detention basins and sediment traps must be periodically removed. The presence of lead in such sediments can cause these sediments to be considered hazardous waste, requiring more involved and expensive disposal management. Lead accumulating in sediment traps and detention basins could become a much greater problem in the future if the EPA changes the toxicity characteristic leaching procedure (TCPL) regarding extractable lead. This could be done based on recent changes in the drinking water standard for lead. Many stormwater detention basin and sediment trap sediments that now just pass the TCLP test (and therefore are classified as a non-hazardous waste) could be classified as hazardous wastes if the TCLP allowable lead limit is adjusted downward. This could increase sediment disposal costs by a factor of ten or more.

Similar problems exist with many other structural BMPs currently used. Those structures were not developed to solve real water quality problems, but were adopted for this use based on misconceptions of how chemical contaminants in urban stormwater runoff impact water quality. Unfortunately, in large part because various professional organizations have compiled lists of BMPs, they have now gained the appearance of credibility and reliability far beyond their real capabilities.

A Recommended Approach

We reviewed an approach that we feel stormwater quality managers should follow in developing control programs for chemical contaminants in urban stormwater.[2] The first step should be to determine whether or not there really is a water quality problem being caused by the current stormwater discharge. As discussed above, the fact that a numeric water quality criterion or standard for a particular chemical(s) is exceeded is not sufficient evidence that a water quality problem exists. Furthermore, simply finding toxicity in tests of urban stormwater runoff should not be interpreted to mean that the designated beneficial uses of the receiving waters is being impaired. The toxicity tests used for domestic and industrial wastewater discharges tend to overestimate the toxicity that will occur in the receiving waters. This overestimation is magnified for urban stormwater discharge evaluation because of the short-term, episodic nature of stormwater discharges.

For example, tests on urban stormwater runoff from many areas indicate a certain level of toxicity. Study after study though has shown that toxicity is not necessarily due to heavy metals even though that may be present in the runoff in elevated concentrations. Rather, the toxicity determined by the tests appears to be caused by pesticides, such as diazinon, commonly used in or around homes. However, it is important not to jump to the conclusion that simply because diazinon is found, and causes toxicity in laboratory tests, that it will cause significant toxicity to aquatic life in the receiving waters. The duration of organism exposure typically used in laboratory toxicity tests usually greatly exceeds the exposure that aquatic organisms receive from stormwater discharges. To define a real water quality problem requires conducting field studies similar to those described in one of our previous papers.[3] This requires using an "aquatic-life hazard assessment framework" that will more realistically determine if toxicity measured in urban stormwater runoff causes adverse problems in the receiving waters or impairs designated uses.

Once a real water quality problem has been identified and reliably traced to urban stormwater runoff as the cause, the sources of available forms of the chemical contaminants responsible for the problem should be determined. Again, the focus should not be on total contaminant concentrations, but rather on the available forms and their respective specific sources. With this type of information it may be possible to control the specific source producing the contaminant(s) in question and thereby eliminate the need to institute control programs for the entire stormwater runoff stream.

Site-Specific Solutions

If it is not possible to control the contaminant responsible for the water quality problem at the source, then a "best management practice" should be developed for the specific pollutants. Such a BMP will likely be quite different from those on the lists of what are currently presented as being available to control "water pollution" from stormwater. Developing an appropriate BMP requires thorough familiarity with aquatic chemistry, aquatic toxicology, and the behavior of various forms of chemical contaminants in different treatment processes. This ensures that the BMP is designed and operated cost-effectively and sufficiently to remove the specific forms of the contaminants of concern, and to provide for proper disposal of residues generated during treatment.

There has been a strong push by numerous groups advocating stringent if not onerous controls on stormwater discharges. These controls in turn affect growth, development, transportation modes (e.g., by recommending decreased automobile use), and so forth in a particular area. The threat of lawsuits against a city, state highway agency, or other entity is a powerful incentive to implement those various controls. Unfortunately in the rush for compliance many of the measures put in place are not cost-effective and may not have been needed in the first place. Capitulating to obviously inappropriate regulatory approaches or to ill-founded legal mandates is strongly contrary to the best interests of the public, especially when available funds for water quality management projects are limited.

The broad mission of community and environmental groups are often worthy endeavors. However, the claim that all stormwater runoff-associated chemical contaminants are having a significant adverse impact on the receiving waterbody, when the technical evidence from aquatic chemistry and aquatic toxicology studies are contrary to that position, is at best counterproductive.

Cost-Effectiveness Is Necessary

In the early to mid-1970s, when the Clean Water Act was developed, the issue of cost-effectiveness regarding pollution control efforts was largely ignored (as well as in the subsequent amendments to the Act). Today, however, the public expects that public officials will use water pollution control funds to address real water quality problems in a technically valid, cost-effective manner. Some states such as California have enacted regulations that require evaluating the cost-effectiveness of, and other economic issues associated with, implementing new water pollution control programs. Furthermore, the voters have made it clear that they are not willing to provide unlimited funds to throw at many different problems.

California's Porter Cologne Act requires that consideration be given to economic issues when adopting regulations for water quality management. However, in 1991 the State Water Resources Control Board (SWRCB) adopted water quality objectives (i.e., certain standards to be met) without properly evaluating the economic issues associated with implementing those regulations, plans, and objectives. Several years ago several cities and an industry filed suit against the SWRCB because of their concern about the overly protective nature of the 1991 water quality objectives. A California court recently determined that the SWRCB did not follow appropriate administrative procedures in developing those objectives. This situation has very important implications for developing technically valid cost-effective approaches.

The public should be entitled to have their elected representatives, councils, and boards, as well as public agencies, such as department of public works, stormwater quality management agencies, and similar entities, critically evaluate the cost-effectiveness of proposed stormwater contaminant control programs before implementation. The public should know, before funds are expended on a structural BMP, what specific improvements in the designated beneficial uses of the receiving waters will accrue as a result of the proposed expenditures. If none can be identified, it is likely then that funding for "contaminant control" facilities would not be forthcoming.

Funds Should be Applied Prudently

Some communities may desire to adopt exceptionally protective measures in an effort to provide safeguards against unexpected impacts from unknown stormwater runoff-associated chemical contaminants. It is recommended that funds be spent determining specific water quality problems caused by the nature of the existing stormwater runoff. Spending money blindly on structural BMPs will likely become nothing more than "make-work" projects without addressing fundamental pollution concerns and without producing viable, realistic returns on the community's investment.

It is strongly recommended that any structural BMP include as part of the facility's construction and operation cost sufficient funds to properly monitor its efficacy. This is necessary to determine if the control measure is actually benefitting the receiving water's designated "beneficial use." Such a monitoring program is significantly different from that typically used for stormwater runoff today. Unfortunately, the typical stormwater monitoring program consists largely of determining total concentrations of a few contaminants upgradient and downgradient from the structural BMP.[4] Such monitoring of chemical concentrations has little or nothing to do with true water quality monitoring. Through properly developed monitoring programs it will be possible to gain information that can help provide guidance to using this particular type of BMP at other locations. It will also provide information on how the particular type of BMP may be modified to improve its efficiency and suitability in addressing real water quality problems.

It is recognized by many that current EPA criteria and state water quality standards should not be used to regulate stormwater runoff-associated contaminants. However, a disturbing trend is developing of using those same criteria and standards for judging a structural BMP's efficiency. That approach is technically invalid and should not be followed.[2] The only way to reliably judge the efficacy is to determine how well the technique effects an improvement in the designated beneficial uses of the receiving waters. This approach costs more than what a public works director may be used to spending on water pollution monitoring programs. However, in the long-term, appropriate field studies that define and determine a program's efficacy will be highly effective in developing future BMPs that will control the adverse impacts of chemical contaminants without exorbitant costs.

Some Final Thoughts

The technical foundation for the EPA's and states' stormwater quality management programs has significant deficiencies. If not addressed in the near-term, these deficiencies will lead to a significant waste of public and private funds by requiring constructing structural BMPs that will have little effect in improving water quality. In many situations such facilities either would be installed for the purposes of removing materials that do not affect the water body's beneficial use or would not be able to remove the adverse materials cost-effectively. It is essential that public works directors and others concerned with developing and implementing urban stormwater quality management programs work closely with state and federal agencies in formulating more technically valid approaches for evaluating the water quality significance of chemical contaminants in urban runoff. Where real water quality problems are found to be caused by stormwater-associated contaminants, work should be directed toward developing management approaches to address these problems without unnecessarily expending funds for unjustified controls.

It is intended that these articles on best management practices for stormwater discharges will aid public works directors, regulatory agencies, municipal officials, and interested community groups in examining the laudable intent to protect water quality in greater detail. It is necessary that these groups continue the discussion on producing the best solution possible, not just an expedient one. □□□

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